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(54) **Polyvinylidene fluoride**

Polyvinylidenefluoride

Fluorure de polyvinylidène

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(73) Proprietor: **AUSIMONT S.p.A.**
I-20121 Milano (IT)

(72) Inventors:
• **Brinati, Giulio**
Milano (IT)
• **Arcella, Vincenzo**
Novara (IT)

• **Albano, Margherita**
Milano (IT)

(74) Representative: **Sama, Daniele, Dr. et al**
Sama Patents
Via Morgagni, 2
20129 Milano (IT)

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EP 0 626 396 B1

Description

The present invention relates to a polyvinylidene fluoride (PVDF) having high mechanical properties and high thermochemical stability, and to the preparation process thereof.

It is known that vinylidene fluoride (VDF) can be polymerized in aqueous emulsion using inorganic or organic peroxides as initiators. Among the latter, di-tert-butylperoxide (DTBP), as described in US Patent 3,193,539, has resulted particularly effective. With such initiator the polymerization is carried out at high temperatures, generally comprised between 120° and 130°C, and at a pressure comprised between 300 and 1000 psig, without employing any chain transfer agent. The PVDF obtained with such process shows a low crystallinity degree, with a high amount of structural defects (tail-to-tail and head-to-head inversions, branchings, microgels), and consequently unsatisfactory mechanical properties and mouldability, quite unsuitable for the manufacture of articles, such as pipes, valves, fittings, tanks, heat exchangers, membranes, flanges, etc. to be employed in the chemical industry.

In US Patent 3,475,396 a VDF polymerization process is described, wherein diisopropyl peroxydicarbonate (IPP) is used as initiator, optionally in the presence of a suitable chain transfer agent. IPP is characterized by a half-life of 1 hour at 61°C, therefore the process can be carried out at lower temperatures in comparison to DTBP, generally comprised between 65° and 85°C, with reaction times lower than 6 hours. The low polymerization temperature allows to obtain a PVDF having high mechanical properties, since the structural defects are drastically reduced and therefore the crystallinity of the product is higher.

The PVDF obtained with the low temperature process mentioned above, though having high crystallinity degree and very good mechanical characteristics, shows poor thermochemical resistance to dehydrofluorination. In fact, on the basis of the experimentation carried out by the Applicant, it has been found that the PVDF obtained at low temperature, if submitted to high temperatures (over 100°C) or contacted with basic solutions (for instance NaOH at 10%), tends to dehydrofluorinate, with formation in the chain of conjugated double bonds of the $-\text{CF}=\text{CH}-\text{CF}=\text{CH}-$ type. The formation of such structural defects, besides conferring undesired colorations, lowers considerably the mechanical resistance of the material, as shown by measurements of chemical stress cracking.

Moreover, the low temperature process shows several drawbacks especially connected to the use of extremely hazardous peroxidic initiators, such as IPP, since explosive also at low temperatures. For instance, IPP has a self-accelerating decomposition temperature (SADT) of about 10°C and requires a shipment temperature lower than -10°C. This requires to take particular safety measures both for transportation and storage, and during its use in the polymerization process. Because of the hazard with such products, in some countries their use on an industrial scale was submitted to severe restrictions.

The Applicant has now surprisingly found that it is possible to obtain a PVDF having high mechanical properties both at room temperature and at high temperatures, having very good processability and high thermochemical resistance to dehydrofluorination, by means of a VDF polymerization process in aqueous emulsion at high temperatures, comprised between 95° and 120°C, in the presence of a chain transfer agent. It is thus possible to obtain, using non-hazardous peroxidic initiators (for instance DTBP), a PVDF particularly suitable to applications where high mechanical properties and thermochemical resistance are required, such as for instance the manufacture of articles for chemical industry (pipes, valves, fittings, tanks, heat exchangers, membranes, flanges, etc.).

It is therefore object of the present invention a polyvinylidene fluoride having a head-to-head and tail-to-tail inversion content comprised between 5 and 5.5% by moles, a yield stress higher than 50 MPa and an elastic modulus higher than 1500 MPa (measured at 23°C according to ASTM Method D-1708), a Melt Flow Index (MFI, measured at 230°C with a 5 kg load according to ASTM Method D-1238) comprised between 1 and 25 g/10', preferably between 3 and 20 g/10'.

It results particularly surprising the fact that, notwithstanding the relatively high inversion content, the mechanical properties of the PVDF object of the present invention, such as the yield stress and the elastic modulus, are high indeed, with values substantially equal to those of the PVDF obtained with a low temperature process. With respect to the latter, the Applicant has found that the presence of a higher inversion content increases the stability to dehydrofluorination. A possible interpretation of this phenomenon, which has a merely speculative character and does not limit the scope of the present invention in any way, is that the presence in the chain of head-to-head $-\text{CF}_2-\text{CF}_2-$ and tail-to-tail $-\text{CH}_2\text{CH}_2-$ defects introduces a discontinuity in the sequence of $-\text{CF}_2-$ and $-\text{CH}_2-$ groups, thus hindering the dehydrofluorination.

The PVDF object of the present invention shows moreover an improved processability if compared to a PVDF obtained at low temperature. The latter, indeed, because of the high molecular rigidity, is characterized, the Melt Flow Index being the same, by higher viscosity values at high rate gradients.

Therefore, with respect to the PVDF obtained at low temperatures, the PVDF object of the present invention combines, the mechanical properties being the same, a high thermal stability to dehydrofluorination with an improved processability.

A further advantage of the PVDF object of the present invention consists in a low microgel content, generally lower than 5% by weight, a value remarkably lower if compared with the product obtained according to the high temperature

processes of the prior art, and substantially equivalent to those obtainable with the low temperature processes. Such a low microgel content ensures very good mechanical properties and high processability.

The PVDF object of the present invention, besides the above mentioned applications in the chemical industry, can be employed in electric and electronic industry for cable coating, or in special applications, such as for instance the production of high resistance fishing threads and strings for musical instruments.

A further object of the present invention consists in a process for preparing the above described polyvinylidene fluoride, which comprises polymerizing vinylidene fluoride in aqueous emulsion in the presence of an organic peroxide and of a chain transfer agent, at a temperature comprised between 95° and 120°C, preferably between 100° and 115°C.

The polymerization pressure can generally vary between 30 and 100 bar, preferably between 40 and 90 bar.

As initiator, any organic peroxide active at the above indicated polymerization temperature can be employed. For example, it can be selected for instance from dialkylperoxides, dialkylperoxycarbonates, dibenzoylperoxide, t-alkylperoxybenzoates, t-alkylperoxypivalates. Among them, the peroxides having a self-accelerating decomposition temperature (SADT) higher than 50°C are particularly preferred, such as for instance: di-tert-butylperoxide, di-tert-butylperoxyisopropylcarbonate, tert-butyl(2-ethyl-hexyl)peroxycarbonate, tert-butylperoxy-3,5,5-trimethylhexanoate.

The initiator quantity is generally comprised between 0.1 and 10 g/l_{H₂O}, preferably between 0.5 and 5 g/l_{H₂O}.

The chain transfer agent is selected from those known in the polymerization of fluorinated monomers, such as for instance: ketones, esters, ethers or aliphatic alcohols having from 3 to 10 carbon atoms, such as acetone, ethylacetate, diethylether, isopropyl alcohol, etc.; chloro(fluoro)carbons, optionally containing hydrogen, having from 1 to 6 carbon atoms, such as chloroform, trichlorofluoromethane; bis(alkyl)carbonates wherein the alkyl has from 1 to 5 carbon atoms, such as bis(ethyl)carbonate, bis(isobutyl)carbonate; etc.

The chain transfer agent is fed into the reactor either continuously or in discrete amounts during the polymerization. It is not advisable feeding all the chain transfer agent at the beginning of the polymerization, since we have noticed that such a feeding method, besides strongly inhibiting the reaction kinetics, causes a worsening of the mechanical and processing properties of the polymer.

Moreover it has been found that a remarkable improvement in the mechanical properties of the final product is obtainable by feeding the chain transfer agent according to the following method. Fixing a total amount of PVDF to be produced, expressed as concentration of the polymer in water (measured as g/l_{H₂O}), equal to Q_{TOT} , and a total amount of chain transfer agent to be fed equal to F_{TOT} , the chain transfer agent is preferably fed in such a way that, by subdividing F_{TOT} into 10 portions F_i ($i=0\div9$), each portion is fed into the reaction system at the concentrations Q_i according to the following law: when $Q_0 = 0$, $F_0 = 0\div0.15 \cdot F_{TOT}$; when $Q_1 = 0.1 \cdot Q_{TOT}$, $F_1 = 0.2\div0.3 \cdot F_{TOT}$; when $Q_2 = 0.2 \cdot Q_{TOT}$, $F_2 = 0.1\div0.15 \cdot F_{TOT}$; when $Q_3 = 0.3 \cdot Q_{TOT}$, $F_3 = 0.05\div0.15 \cdot F_{TOT}$; when $Q_4 = 0.4 \cdot Q_{TOT}$, $F_4 = 0.05\div0.15 \cdot F_{TOT}$; when $Q_5 = 0.5 \cdot Q_{TOT}$, $F_5 = 0.05\div0.10 \cdot F_{TOT}$; when $Q_6 = 0.6 \cdot Q_{TOT}$, $F_6 = 0.05\div0.10 \cdot F_{TOT}$; when $Q_7 = 0.7 \cdot Q_{TOT}$, $F_7 = 0\div0.08 \cdot F_{TOT}$; when $Q_8 = 0.8 \cdot Q_{TOT}$, $F_8 = 0\div0.08 \cdot F_{TOT}$; when $Q_9 = 0.9 \cdot Q_{TOT}$, $F_9 = 0\div0.08 \cdot F_{TOT}$; the sum of the quantities F_i being equal to F_{TOT} .

The total amount of chain transfer agent added during the polymerization (F_{TOT}) depends both on the effectiveness of the chain transfer agent itself, and on the molecular weight intended for the final product. In any event, such amount must be such that to obtain MFI values within the above indicated range, and it is generally comprised between 0.05 and 5%, preferably between 0.1 and 2.5% by weight with respect to the total monomer quantity fed into the reactor.

A suitable surfactant is added to the reaction medium to stabilize the aqueous emulsion (see for instance those described in US patents 4,360,652 and 4,025,709). Generally, they are fluorinated surfactants, selected from products of the general formula:



where R_f is a (per)fluoroalkyl chain C_5-C_{16} or a (per)fluoropolyoxyalkylene chain, $X^{\cdot-}$ is $-COO^{\cdot-}$ or $-SO_3^{\cdot-}$, M^+ is selected from: H^+ , NH_4^+ , alkali metal ion. Among the most commonly employed we cite: ammonium perfluoro-octanoate; (per)fluoropolyoxyalkylenes end-capped with one or more carboxyl groups; salts of sulphonic acids of formula $R_f-C_2H_4SO_3H$, where R_f is a C_4-C_{10} perfluoroalkyl (see US Patent 4,025,709); etc.

The process object of the present invention can be carried out in the presence of an emulsion or, preferably, of a microemulsion of perfluoropolyoxyalkylenes, according to what described in US Patents 4,789,717 and US 4,864,006, which are herein incorporated by reference, or also in presence of a microemulsion of fluoropolyoxyalkylenes having hydrogenated end groups and/or hydrogenated repetitive units, according to what described in Italian patent application M193A/001007, filed on May 18, 1993 in the name of the Applicant.

A mineral oil or a paraffin, liquid at the polymerization temperature, can be added to the reaction mixture, in order to inhibit the polymer coagulation and avoiding its adhesion to the reactor walls.

Some working examples of the invention are reported hereinunder, whose aim is merely illustrative but not limitative of the scope of the invention itself.

EXAMPLE 1

In a 10 l vertical reactor, equipped with a stirrer working at 480 rpm, 6.5 l of H₂O and 35 g of paraffin wax (product AGIP^(R) 122-126 having a melt temperature of 50-52°C) were charged. The reactor was then heated to the working temperature of 115°C and brought to the pressure of 44 relative bars by feeding VDF. The VDF is continuously fed during the polymerization so as to keep the pressure constant. 500 ml of a 1.820% by weight aqueous solution of perfluorooctanoic acid potassium salt and 23.7 g of di-tert-butylperoxide (DTBP) were then added. During the polymerization, 0.082 mols of chloroform as chain transfer agent, subdivided into 10 portions, were fed into the reactor.

Fixing a total amount of 1000 g of polymer to be produced, corresponding to a final polymer concentration in water equal to 143.0 g/l_{H₂O}, chloroform was fed in 10 portions at regular intervals of 10% of increase in the polymer concentration with respect to the final concentration, according to the following scheme:

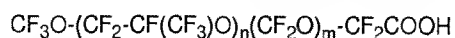
Polymer concentration (g/l _{H₂O})	Added amount of chain transfer agent (mols)
0	0.005 (6.1%)
14.3	0.018 (22.0%)
28.6	0.010 (12.2%)
42.9	0.009 (11.0%)
57.2	0.008 (9.8%)
71.5	0.007 (8.5%)
85.8	0.007 (8.5%)
100.1	0.006 (7.3%)
114.4	0.006 (7.3%)
128.7	0.006 (7.3%)
143.0	---

The polymer concentration in the reaction medium was monitored by measuring the amount of gaseous monomer fed into the reactor after the initial loading phase.

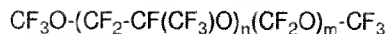
After 290 minutes the desired polymer concentration (143.0 g/l_{H₂O}) was reached, hence the VDF feeding was stopped and the latex discharged from the reactor (solid concentration equal to 12.5% by weight). The polymer was coagulated, washed with demineralized water and dried at 75°C for 24 hours. The so obtained product was then reduced in the form of pellets by extrusion and characterized. The data are reported in Table 1. The MFI was measured at 230°C with a 5 kg load according to ASTM D-1238 Method, the mechanical properties were determined at 23° and 125°C according to ASTM D-1708 Method. By means of differential scanning calorimetry (DSC) the second melting enthalpy (ΔH_f), the second melting temperature (T_f) and the second recrystallization enthalpy (ΔH_{xx}) were determined. The inversion percentage was determined, according to known techniques, by ¹⁹F-NMR analysis. A PVDF sample was dissolved in dimethylacetamide at 50°C and on the so obtained solution the weight percentage of microgels was determined by means of ultracentrifugation (at 20,000 rpm for 90 minutes at room temperature).

EXAMPLE 2Preparation of a perfluoropolyoxyalkylene microemulsion.

In a glass vessel equipped with a stirrer, 7.8 ml of the compound of formula:



having $n/m = 10$ and an average molecular weight of 600, were mixed under mild stirring with 7.8 ml of NH₄OH at 30% by volume. 15.6 ml of demineralized water were then added. To the so obtained solution 4.7 ml of Galden^(R) DO2 of formula:



having $n/m = 20$ and an average molecular weight of 450, were added. By heating to 85°C the microemulsion was obtained, which appears as a thermodynamically stable, limpid solution.

Polymerization reaction

Example 1 was repeated in the same conditions, except that in this case, before starting adding DTBP, the whole microemulsion previously prepared was fed into the autoclave and heated to 85°C.

After 180 minutes of reaction, the desired concentration of 143.0 g/l_{H2O} was reached, hence the VDF flow was stopped and the latex discharged, from which the polymer was separated and characterized as described in Example 1. The data are reported in Table 1.

EXAMPLE 3

Example 1 was repeated in the same conditions, varying only the chain transfer agent feeding law, according to the following scheme:

Polymer concentration (g/l _{H2O})	Added amount of chain transfer agent (mols)
0	0.005 (6.1%)
14.3	0.009 (11.0%)
28.6	0.008 (9.8%)
42.9	0.009 (11.0%)
57.2	0.008 (9.8%)
71.5	0.009 (11.0%)
85.8	0.008 (9.8%)
100.1	0.009 (11.0%)
100.1	0.008 (9.8%)
128.7	0.009 (11.0%)
143.0	---

After 270 minutes the desired polymer concentration (143.0 g/l_{H2O}) was reached. The polymer was separated and characterized as described in Example 1. The data are reported in Table 1.

EXAMPLE 4

Example 1 was repeated in the same conditions, except that the amount of chloroform used as chain transfer agent is equal to 0.05 total moles, fed according to the following scheme:

Polymer concentration (g/l _{H2O})	Added amount of chain transfer agent (mols)
0	0.005 (10.0%)
14.3	0.005 (10.0%)
28.6	0.005 (10.0%)
42.9	0.005 (10.0%)
57.2	0.005 (10.0%)
71.5	0.005 (10.0%)
85.8	0.005 (10.0%)
100.1	0.005 (10.0%)
114.4	0.005 (10.0%)
128.6	0.005 (10.0%)
143.0	---

After 227 minutes the desired polymer concentration (143.0 g/l_{H2O}) was reached. The polymer was separated and characterized as described in Example 1. The data are reported in Table 1.

EXAMPLE 5 (comparative)

Example 1 was repeated in the same conditions, except that the polymerization temperature was fixed to 125°C and no chain transfer agent was used.

After 90 minutes of reaction, the polymer was separated and characterized as described in Example 1. The data are reported in Table 1.

EXAMPLE 6 (comparative)

Example 1 was repeated in the same conditions, except that the polymerization temperature was fixed to 125°C and 0.025 total moles of chloroform were employed as chain transfer agent, fed according to the following scheme:

Polymer concentration (g/l _{H2O})	Added amount of chain transfer agent (mols)
0	0.0025 (10.0%)
14.3	0.0025 (10.0%)
28.6	0.0025 (10.0%)
42.9	0.0025 (10.0%)
57.2	0.0025 (10.0%)
71.5	0.0025 (10.0%)
85.8	0.0025 (10.0%)
100.1	0.0025 (10.0%)
114.4	0.0025 (10.0%)
128.7	0.0025 (10.0%)
143.0	---

After 120 minutes the desired polymer concentration (143.0 g/l_{H2O}) was reached. The polymer was separated and characterized as described in Example 1. The data are reported in Table 1.

EXAMPLE 7 (comparative)

Following the operative modalities described in Example 1, VDF was polymerized at 75°C using as initiator 1.4 g of isopropylperoxydicarbonate (IPP), fed into the autoclave in the form of aqueous emulsion containing 2% by weight of IPP and 0.2% by weight of perfluorooctanoic acid potassium salt. 500 ml of a 1.820% by weight aqueous solution of perfluorooctanoic acid potassium salt were added to the reaction mixture. As chain transfer agent CFCI₃ was employed, in a total amount of 2.5 g, fed in a single portion at the beginning of the polymerization.

After 120 minutes the desired polymer concentration (143.0 g/l_{H2O}) was reached. The polymer was separated and characterized as described in Example 1. The data are reported in Table 1.

TABLE 1

PROPERTIES	EX.	1 EX.	2 EX. 3	EX. 4	EX. 5 ^(*)	EX. 6 ^(*)	EX. 7 ^(*)
MFI (g/10')	18.0	7.0	16.0	3.0	0.1	19	13
MICROGELS (% weight)	< 5	< 5	< 5	< 5	40	< 5	< 5
ΔH_f (cal/g)	14.2	13.8	13.9	13.5	12.1	12.8	14.8
T_f (°C)	165	165	164	164	159	161	168
$ \Delta H_{xx} $ (cal/g)	13.7	13.5	13.5	13.1	11.9	12.1	13.7
INVERSIONS (moles %)	5.3	5.3	5.3	5.3	5.3	5.4	4.6
TENSILE STRESS RESISTANCE (23°C)							
Elastic modulus (MPa)	1765	1690	1700	1550	1200	1450	1700
Yield point (MPa)	54	53	53	51	44	46	53
Stress at break (MPa)	31	35	18	30	31	30	32
Elongation at break (%)	40	50	35	50	180	25	50
TENSILE STRESS RESISTANCE (125°C)							
Elastic Modulus (MPa)	320	314	310	300	195	220	340
Yield Point (MPa)	12	11	11	11	8	9	13
Stress at break (MPa)	30	35	28	33	30	30	37
Elongation at break (%)	720	760	710	760	800	600	700

(*) comparative examples

Samples of the PVDF obtained in Examples 1, 5, and 7 were subjected to chemical resistance tests according to the following method.

The PVDF was subjected to compression moulding to obtain plates of 3.5 g. The specimens were immersed in a NaOH solution (40% weight/volume) at 100°C for different times (16, 38, and 62 hours). After removing the polymer, the quantity of F⁻ ions present in the aqueous basic solution was determined by ionic chromatography, and expressed as mg of F⁻ per Kg of polymer. Since the F⁻ ions derive from the decomposition of the polymer by dehydrofluorination, the lower the quantity of F⁻ ions produced, the higher the polymer stability to dehydrofluorination. The obtained results are reported in Table 2, from which it can be derived that the PVDF according to the present invention (Ex.1) has a stability to dehydrofluorination significantly higher than that of the PVDF obtained according to the low temperature process (Ex.7), and substantially equivalent to that of the PVDF obtained according to the high temperature process (Ex.5).

TABLE 2

TESTED PRODUCT	POLYM. TEMP. (°C)	PRODUCED F ⁻ IONS (mg/Kg of polymer)		
		after 16 hrs	after 38 hrs	after 62 hrs
EX.1	115	6	4	6
EX.5 ^(*)	125	2	3	5
EX.7 ^(*)	75	3	5	11

(*) comparative

Claims

1. Polyvinylidenefluoride having a head-to-head and tail-to-tail inversion content comprised between 5 and 5.5% by mols, a yield point higher than 50 MPa and an elastic modulus higher than 1500 MPa measured at 23°C according to ASTM D-1708 Method, a Melt Flow Index (MFI), measured at 230°C with a 5 kg load according to ASTM D-1238 Method comprised between 1 and 25 g/10 minute.
2. Polyvinylidenefluoride according to claim 1, having a MFI comprised between 3 and 20 g/10 minute.
3. Polyvinylidenefluoride according to claim 1 or 2, having a microgel content lower than 5% by weight.
4. Process for preparing the polyvinylidenefluoride according to the previous claims, which comprises polymerizing vinylidene fluoride in aqueous emulsion in the presence of an organic peroxide and of a chain transfer agent, at a temperature comprised between 95° and 120°C.
5. Process according to claim 4, wherein the polymerization temperature is comprised between 100° and 115°C.
6. Process according to claims 4 or 5, wherein the polymerization pressure is comprised between 30 and 100 bar.
7. Process according to claim 6, wherein the polymerization pressure is comprised between 40 and 90 bar.
8. Process according to anyone of claims from 4 to 7, wherein the organic peroxide is selected from dialkylperoxides, dialkylperoxycarbonates, dibenzoylperoxide, t-alkylperoxybenzoates, t-alkylperoxypivalates, having a self-accelerating decomposition temperature (SADT) higher than 50°C.
9. Process according to claim 8, wherein the organic peroxide is selected from: di-tert-butylperoxide, di-tert-butylperoxyisopropylcarbonate, tert-butyl(2-ethylhexyl)peroxycarbonate, tert-butylperoxy-3,5,5-trimethylhexanoate.
10. Process according to anyone of claims from 4 to 9, wherein the chain transfer agent is selected from: ketones, esters, ethers or aliphatic alcohols having from 3 to 10 carbon atoms; chloro(fluoro)carbons, optionally containing hydrogen, having from 1 to 6 carbon atoms; bis(alkyl)carbonates wherein the alkyl has from 1 to 5 carbon atoms.
11. Process according to anyone of claims from 4 to 10, wherein the chain transfer agent is fed into the reactor continuously or in discrete amounts during the polymerization.
12. Process according to claim 11, wherein, fixing a total amount of PVDF to be produced, expressed as concentration of the polymer in water, equal to Q_{TOT} , and a total amount of chain transfer agent to be fed equal to F_{TOT} , the chain transfer agent is fed so as, subdividing F_{TOT} into 10 portions F_i ($i=0\div9$), each portion is fed into the reaction system at the concentrations Q_i according to the following law: when $Q_0 = 0$, $F_0 = 0\div0.15 \cdot F_{TOT}$; when $Q_1 = 0.1 \cdot Q_{TOT}$, $F_1 = 0.2\div0.3 \cdot F_{TOT}$; when $Q_2 = 0.2 \cdot Q_{TOT}$, $F_2 = 0.1\div0.15 \cdot F_{TOT}$; when $Q_3 = 0.3 \cdot Q_{TOT}$, $F_3 = 0.05\div0.15 \cdot F_{TOT}$; when $Q_4 = 0.4 \cdot Q_{TOT}$, $F_4 = 0.05\div0.15 \cdot F_{TOT}$; when $Q_5 = 0.5 \cdot Q_{TOT}$, $F_5 = 0.05\div0.10 \cdot F_{TOT}$; when $Q_6 = 0.6 \cdot Q_{TOT}$, $F_6 = 0.05\div0.10 \cdot F_{TOT}$; when $Q_7 = 0.7 \cdot Q_{TOT}$, $F_7 = 0\div0.08 \cdot F_{TOT}$; when $Q_8 = 0.8 \cdot Q_{TOT}$, $F_8 = 0\div0.08 \cdot F_{TOT}$; when $Q_9 = 0.9 \cdot Q_{TOT}$, $F_9 = 0\div0.08 \cdot F_{TOT}$; the sum of the quantities F_i being equal to F_{TOT} .
13. Polyvinylidenefluoride obtainable by the process according to claims from 4 to 12.

Patentansprüche

1. Polyvinylidenfluorid mit einem Kopf-an-Kopf- und Schwanz-an-Schwanz-Inversionsgehalt zwischen 5 und 5,5 Mol-%, einer Streckspannung von größer als 50 MPa und einem Elastizitätsmodul von größer als 1500 MPa, gemessen bei 23°C gemäß dem Verfahren von ASTM D-1708, einem Schmelzflußindex (MFI), gemessen bei 230°C mit einer Last von 5 kg gemäß dem Verfahren von ASTM D-1238, zwischen 1 und 25 g/10 Minuten.
2. Polyvinylidenfluorid nach Anspruch 1 mit einem MFI zwischen 3 und 20 g/10 Minuten.
3. Polyvinylidenfluorid nach Anspruch 1 oder 2 mit einem Mikrogel-Gehalt unter 5 Gewichts-%.

4. Verfahren zur Herstellung des Polyvinylidenfluorids gemäß den vorangehenden Ansprüchen, umfassend die Polymerisation von Vinylidenfluorid in wäßriger Emulsion in Anwesenheit eines organischen Peroxids und eines Kettenübertragungsmittels bei einer Temperatur zwischen 95 und 120°C.
5. Verfahren nach Anspruch 4, in welchem die Polymerisationstemperatur zwischen 100 und 115°C liegt.
6. Verfahren nach den Ansprüchen 4 oder 5, in welchem der Polymerisationsdruck zwischen 30 und 100 bar liegt.
7. Verfahren nach Anspruch 6, in welchem der Polymerisationsdruck zwischen 40 und 90 bar liegt.
8. Verfahren nach irgendeinem der Ansprüche 4 bis 7, in welchem das organische Peroxid aus Dialkylperoxiden, Dialkylperoxycarbonaten, Dibenzoylperoxid, t-Alkylperoxybenzoaten, t-Alkylperoxypivalaten, mit einer selbstbeschleunigenden Zersetzungstemperatur (SADT) von höher als 50°C, ausgewählt ist.
9. Verfahren nach Anspruch 8, in welchem das organische Peroxid aus Di-tert-butylperoxid, Di-tert-butylperoxyisopropylcarbonat, tert-Butyl(2-ethylhexyl)peroxycarbonat, tert-Butylperoxy-3,5,5-trimethylhexanoat ausgewählt ist.
10. Verfahren nach irgendeinem der Ansprüche 4 bis 9, in welchem das Kettenübertragungsmittel ausgewählt ist aus: Ketonen, Estern, Ethern oder aliphatischen Alkoholen mit 3 bis 10 Kohlenstoffatomen; Chlor(fluor)kohlenstoffen, gegebenenfalls Wasserstoff enthaltend, mit 1 bis 6 Kohlenstoffatomen; Bis(alkyl)carbonaten, in denen das Alkyl 1 bis 5 Kohlenstoffatome aufweist.
11. Verfahren nach irgendeinem der Ansprüche 4 bis 10, in welchem das Kettenübertragungsmittel kontinuierlich oder portionsweise während der Polymerisation in den Reaktor eingeführt wird.
12. Verfahren nach Anspruch 11, in welchem, indem man eine Gesamtmenge von herzustellendem PVDF, ausgedrückt als Konzentration des Polymers in Wasser, gleich Q_{TOT} , und eine Gesamtmenge an einzuführendem Kettenübertragungsmittel gleich F_{TOT} , festlegt, das Kettenübertragungsmittel so zugeführt wird, daß, indem man F_{TOT} in 10 Portionen F_i ($i = 0 \div 9$) aufteilt, jede Portion gemäß der folgenden Gesetzmäßigkeit bei den Konzentrationen Q_i in das Reaktionssystem eingeführt wird: wenn $Q_0 = 0$, $F_0 = 0 \div 0,15 \cdot F_{TOT}$; wenn $Q_1 = 0,1 \cdot Q_{TOT}$, $F_1 = 0,2 \div 0,3 \cdot F_{TOT}$; wenn $Q_2 = 0,2 \cdot Q_{TOT}$, $F_2 = 0,1 \div 0,15 \cdot F_{TOT}$; wenn $Q_3 = 0,3 \cdot Q_{TOT}$, $F_3 = 0,005 \div 0,15 \cdot F_{TOT}$; wenn $Q_4 = 0,4 \cdot Q_{TOT}$, $F_4 = 0,05 \div 0,15 \cdot F_{TOT}$; wenn $Q_5 = 0,5 \cdot Q_{TOT}$, $F_5 = 0,05 \div 0,10 \cdot F_{TOT}$; wenn $Q_6 = 0,6 \cdot Q_{TOT}$, $F_6 = 0,05 \div 0,10 \cdot F_{TOT}$; wenn $Q_7 = 0,7 \cdot Q_{TOT}$, $F_7 = 0 \div 0,08 \cdot F_{TOT}$; wenn $Q_8 = 0,8 \cdot Q_{TOT}$, $F_8 = 0 \div 0,08 \cdot F_{TOT}$; wenn $Q_9 = 0,9 \cdot Q_{TOT}$, $F_9 = 0 \div 0,08 \cdot F_{TOT}$; wobei die Summe der Mengen F_i gleich F_{TOT} ist.
13. Polyvinylidenfluorid, erhältlich durch das Verfahren nach den Ansprüchen 4 bis 12.

Revendications

1. Poly(fluorure de vinylidène) ayant une teneur en inversions tête-à-tête et queue-à-queue comprise entre 5 et 5,5% en moles, une limite élastique supérieure à 50 MPa et un module élastique supérieur à 1500 MPa mesurés à 23°C conformément à la Méthode ASTM D-1708, un Indice de Fusion (MFI), mesuré à 230°C avec une charge de 5 kg conformément à la Méthode ASTM D-1238, compris entre 1 et 25 g/10 minutes.
2. Poly(fluorure de vinylidène) selon la revendication 1, ayant un MFI compris entre 3 et 20 g/10 minutes.
3. Poly(fluorure de vinylidène) selon l'une des revendications 1 ou 2, ayant une teneur en microgels inférieure à 5% en poids.
4. Procédé de préparation du poly(fluorure de vinylidène) tel que défini à l'une quelconque des revendications précédentes, qui comprend la polymérisation du fluorure de vinylidène en émulsion aqueuse en présence d'un peroxyde organique et d'un agent de transfert de chaîne, à une température comprise entre 95° et 120°C.
5. Procédé selon la revendication 4, dans lequel la température de polymérisation est comprise entre 100° et 115°C.
6. Procédé selon l'une des revendications 4 ou 5, dans lequel la pression de polymérisation est comprise entre 30 et 100 bars.

7. Procédé selon la revendication 6, dans lequel la pression de polymérisation est comprise entre 40 et 90 bars.
8. Procédé selon l'une quelconque des revendications 4 à 7, dans lequel le peroxyde organique est choisi parmi les peroxydes de dialkyle, les peroxycarbonates de dialkyle, le peroxyde de dibenzoyl, les peroxybenzoates de t-alkyle, les peroxyphthalates de t-alkyle, ayant une température de décomposition à auto-accélération (SADT) supérieure à 50°C.
9. Procédé selon la revendication 8, dans lequel le peroxyde organique est choisi parmi : le peroxyde de di-tert-butyle, le peroxyisopropylcarbonate de di-tert-butyle, le peroxycarbonate de tert-butyle et de (2-éthylhexyle), le peroxy-3,5,5-triméthylhexanoate de tert-butyle.
10. Procédé selon l'une quelconque des revendications 4 à 9, dans lequel l'agent de transfert de chaîne est choisi parmi : les cétones, les esters, les éthers ou les alcools aliphatiques ayant de 3 à 10 atomes de carbone ; les chloro(fluoro)carbures, contenant facultativement de l'hydrogène, ayant de 1 à 6 atomes de carbone ; les bis(alkyl)carbonates, dans lesquels l'alkyle a de 1 à 5 atomes de carbone.
11. Procédé selon l'une quelconque des revendications 4 à 10, dans lequel l'agent de transfert de chaîne est introduit dans le réacteur en continu ou en quantités discrètes pendant la polymérisation.
12. Procédé selon la revendication 11, dans lequel, en fixant une quantité totale de PVDF devant être produite, exprimée en tant que concentration du polymère dans l'eau, égale à Q_{TOT} , et une quantité totale d'agent de transfert de chaîne devant être introduite égale à F_{TOT} , l'agent de transfert de chaîne est introduit de telle sorte qu'en subdivisant F_{TOT} en 10 fractions F_i ($i = 0:9$), chaque fraction est introduite dans le système réactionnel aux concentrations Q_i conformément à la loi suivante : lorsque $Q_0 = 0$, $F_0 = 0 \div 0,15 \cdot F_{TOT}$; lorsque $Q_1 = 0,1 \cdot Q_{TOT}$, $F_1 = 0,2 \div 0,3 \cdot F_{TOT}$; lorsque $Q_2 = 0,2 \cdot Q_{TOT}$, $F_2 = 0,1 \div 0,15 \cdot F_{TOT}$; lorsque $Q_3 = 0,3 \cdot Q_{TOT}$, $F_3 = 0,05 \div 0,15 \cdot F_{TOT}$; lorsque $Q_4 = 0,4 \cdot Q_{TOT}$, $F_4 = 0,05 \div 0,15 \cdot F_{TOT}$; lorsque $Q_5 = 0,5 \cdot Q_{TOT}$, $F_5 = 0,05 \div 0,10 \cdot F_{TOT}$; lorsque $Q_6 = 0,6 \cdot Q_{TOT}$, $F_6 = 0,05 \div 0,10 \cdot F_{TOT}$; lorsque $Q_7 = 0,7 \cdot Q_{TOT}$, $F_7 = 0 \div 0,08 \cdot F_{TOT}$; lorsque $Q_8 = 0,8 \cdot Q_{TOT}$, $F_8 = 0 \div 0,08 \cdot F_{TOT}$; lorsque $Q_9 = 0,9 \cdot Q_{TOT}$, $F_9 = 0 \div 0,08 \cdot F_{TOT}$; la somme des quantités F_i étant égale à F_{TOT} .
13. Poly(fluorure de vinylidène) pouvant être obtenu par le procédé tel que défini à l'une des revendications 4 à 12.